Solar Imaging Radio Array (SIRA):

Imaging solar, magnetospheric, and astrophysical sources at < 15 MHz

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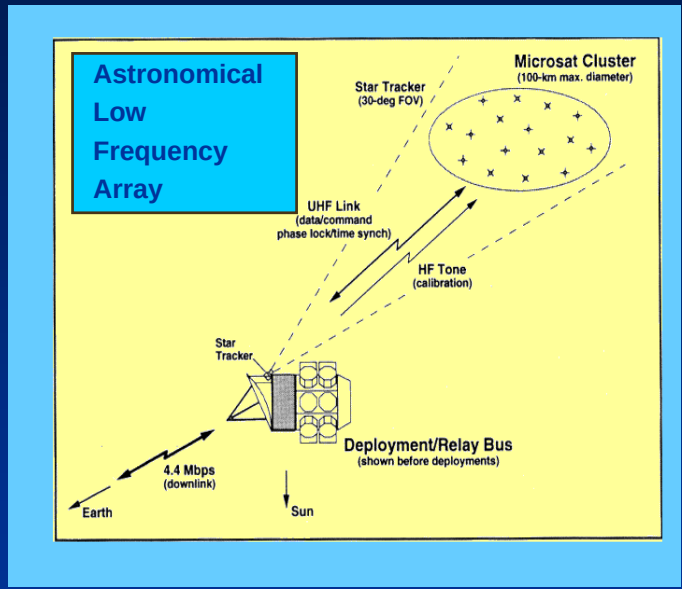
Outline

- Background & history of low frequency radio arrays proposed for space-based operation
- SIRA solar-heliospheric science goals
- SIRA astrophysics science goals (brief)
- SIRA mission design
  - Orbit
  - Constellation/mission hardware
  - Instrument parameters
  - Science team

Website: sira.gsfc.nasa.gov

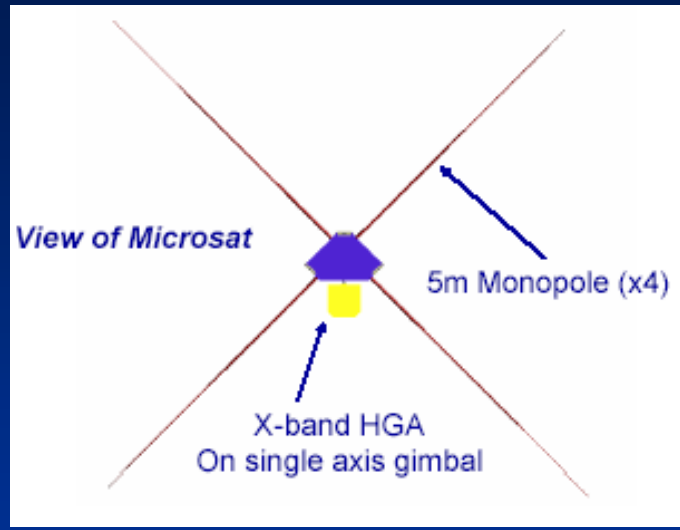
Low Frequency Space Arrays (LFSAs)

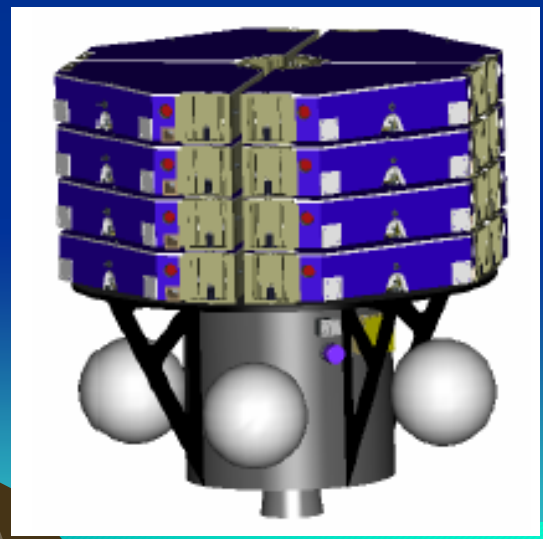
- Several LFSA proposals in 1990's
- 2 NASA MIDEX proposals:
  - ALFA 1 (1995) – primarily astrophysics
  - ALFA 2 (1998) – submitted to both Astrophysics and Sun-Earth
- Current status: only viable submission is to NASA SEC (Sun Earth Connections) theme
- NASA MIDEX is the best slot, but cost cap ($170 M excluding launch vehicle) is tight



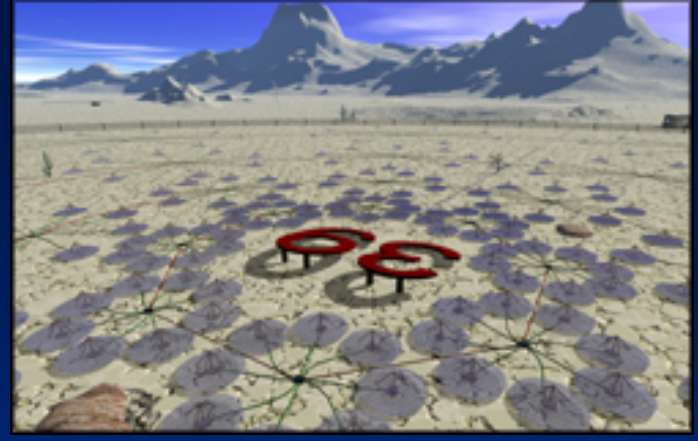
SIRA mission design

- Orbital Sciences Corp. recently selected as the spacecraft provider
- 12 – 16 microsats (concept at right from Orbital Sciences Corp. proposal)
- Planned orbit is “retrograde” at ~500,000 km (~80 R_E) from Earth
- Spring forced deployment provides initial Δv to put μsats on 10 km sphere
- “Pathfinder” for microsat constellation missions & space-based interferometry



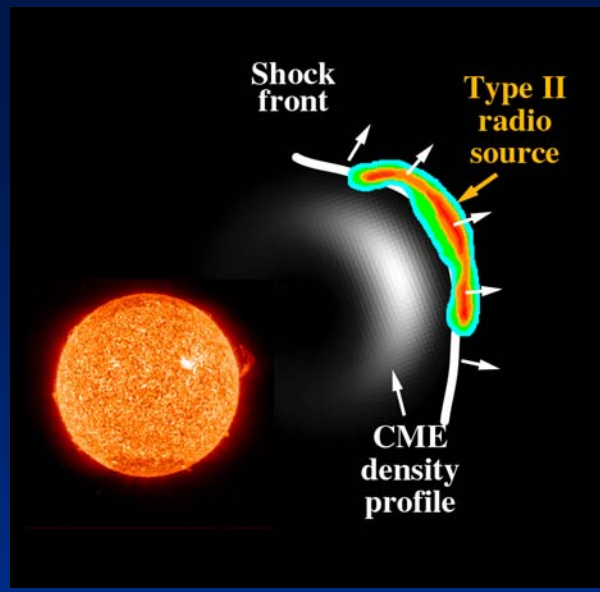


Relation to "Long Wavelength Arrays"



- SIRA extends some LWA/LOFAR observations by 2.5 orders of magnitude to <100 kHz
- SIRA will connect LWA/LOFAR solar/coronal observations to the heliosphere and Earth
- SIRA will benefit substantially from LWA and LOFAR observations of sources > 15 MHz
- Similarities in imaging requirements argue for collaborative efforts

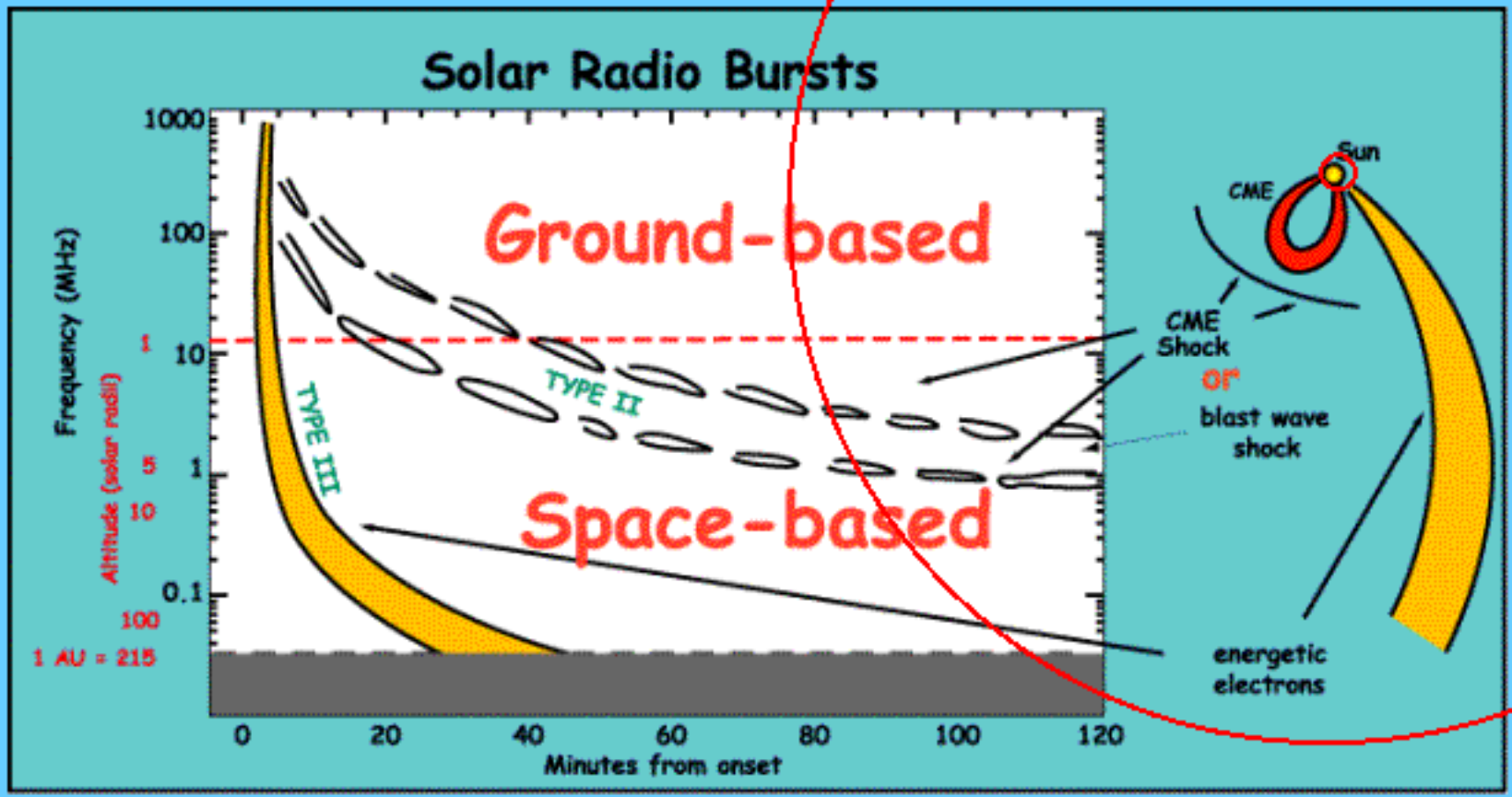
SIRA science targets



- CME structure, propagation, & evolution
- Topologies of interacting CMEs
- Evolution of intermediate-scale solar wind structure
- Structure and dynamics of energetic electron beams
- Space weather prediction using radio imaging
- Meso-scale magnetospheric response to space weather
- Mapping “astrophysical” sources

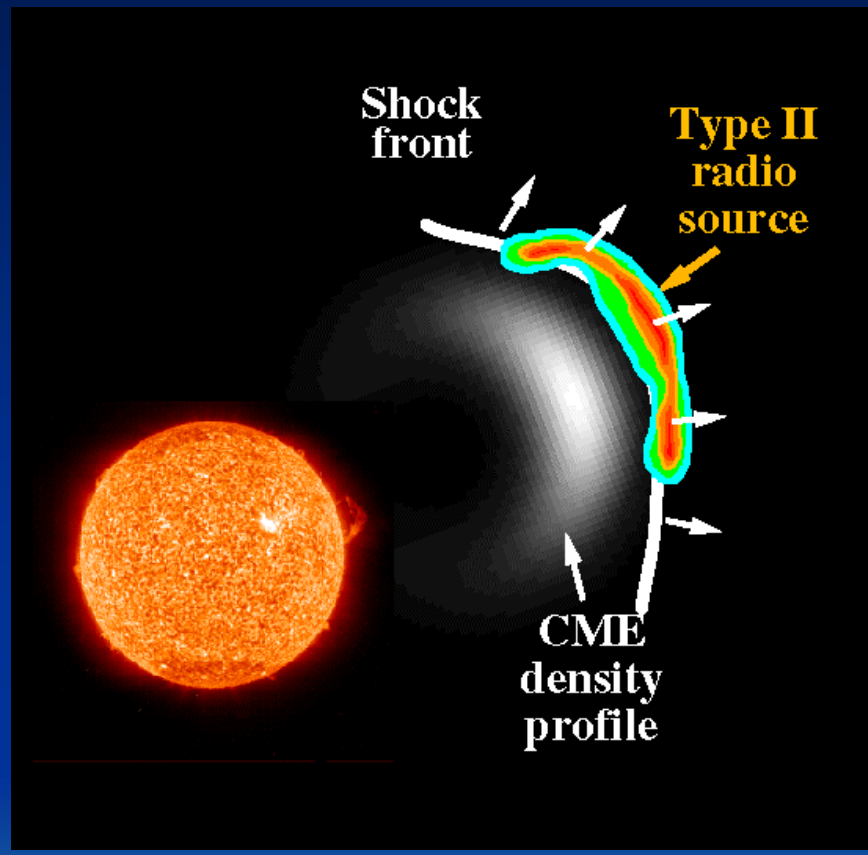
Solar Radio Astronomy

1 minute tutorial

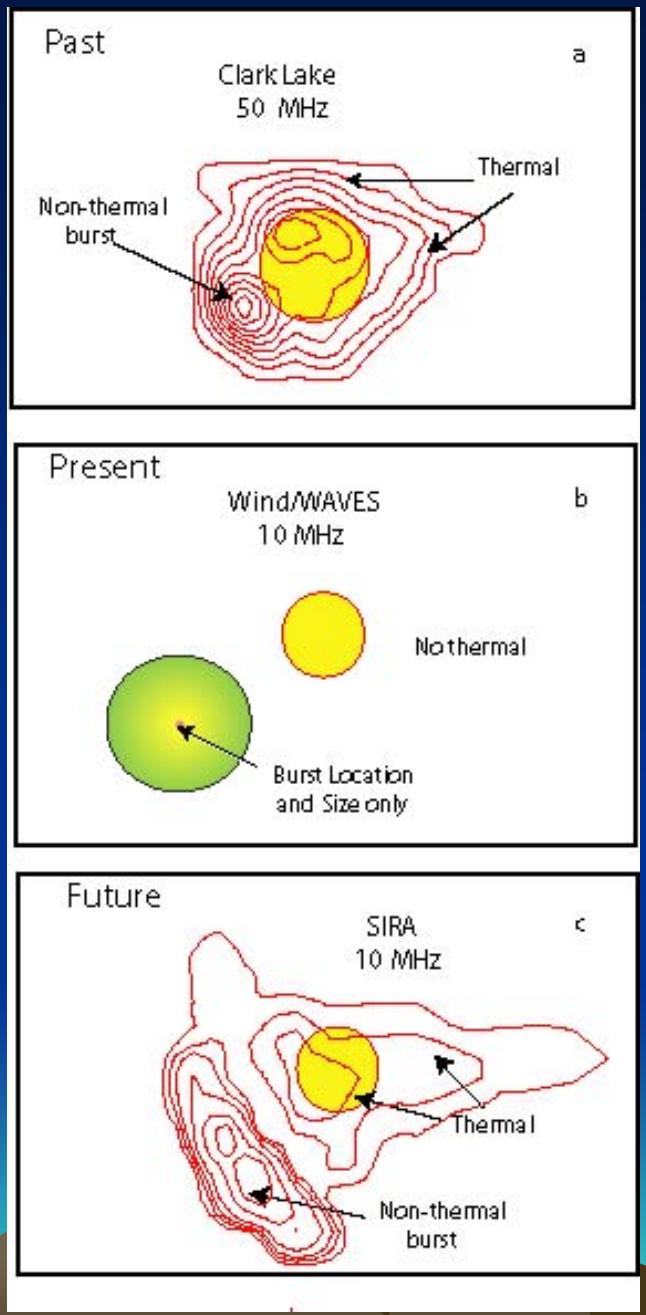


Primary SIRA science goal: Focus on CMEs

- understand CME propagation, evolution, and effect on the terrestrial magnetosphere
- observe type II radio emission from CME-driven coronal &/or interplanetary shock
- observe the over-dense CME regions backlit by type IIIs
- observe fast-drift radio bursts associated with post-CME reconnection



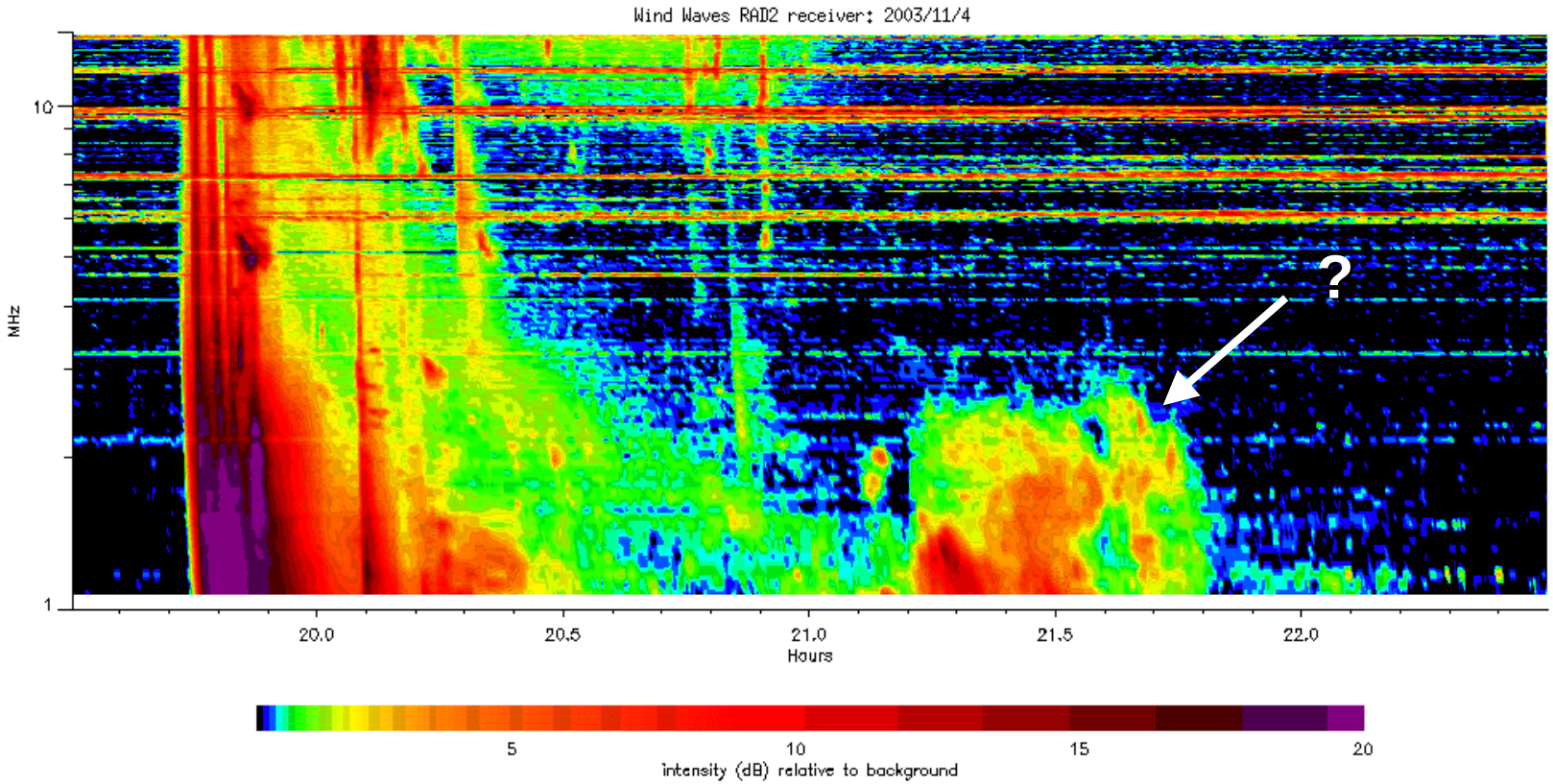
Note that these observations are complementary to coronagraphs, all-sky imagers, and scintillation obs.



Solar radio data - past and present

- Clark Lake Radio Obs. image shows thermal sun and non-thermal burst at 50 MHz
- Single dipoles (like Wind/ Waves) provide direction and source size (w/ intensity model)
- SIRA will provide the first high resolution imaging of radio bursts at frequencies < 15 MHz

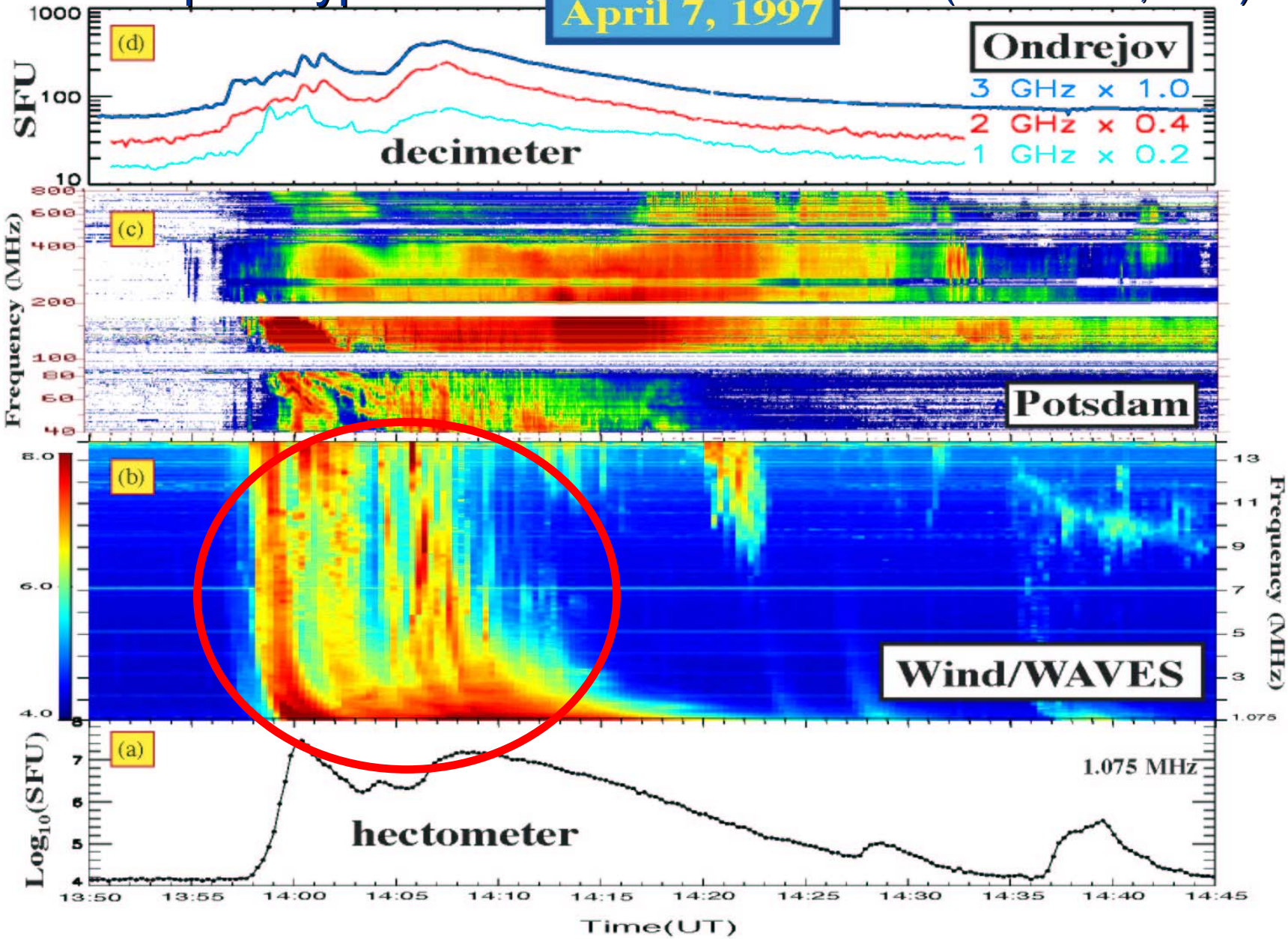
Colliding CMEs?



SIRA radio images, in combination with white light coronagraph images, would resolve the controversy surrounding the source of “type II enhancements”

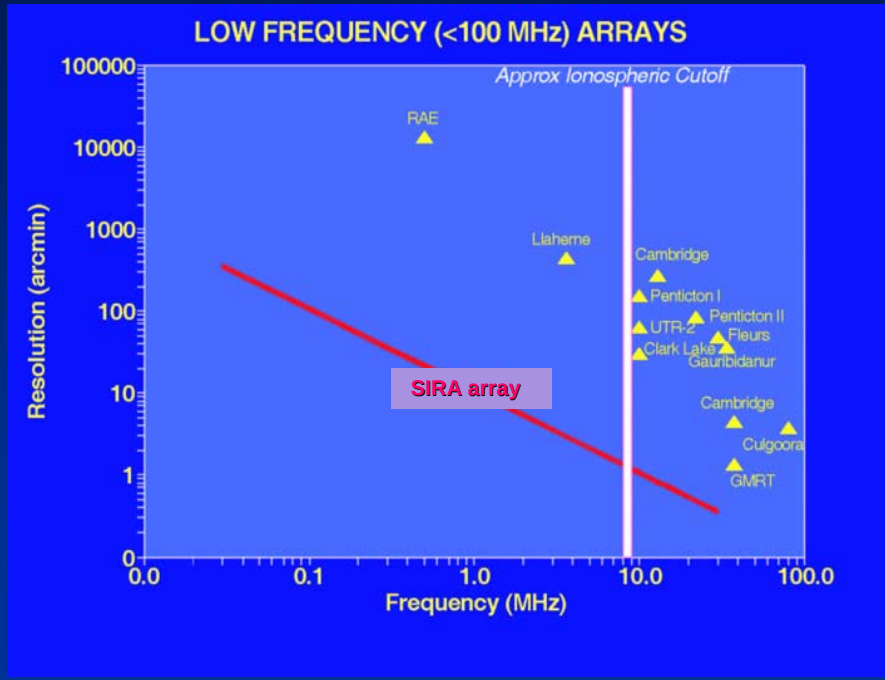
Complex Type IIIs

(Reiner et al, 2000)



Astrophysics Targets

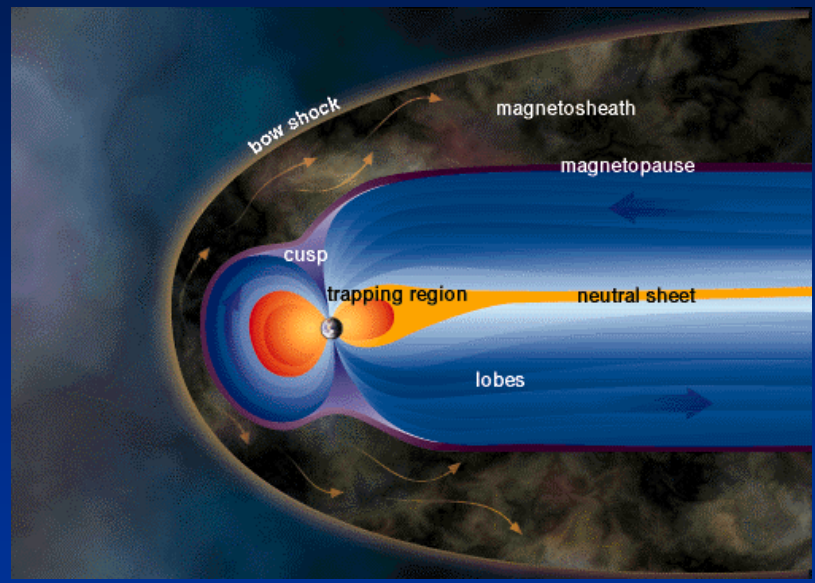
- Cosmology and large scale structure; earliest clusters
- Formation and evolution of galaxies: “fossil” galaxies
- Structure, properties, and statistics of supernova remnants (SNRs): CR acceleration sites
- Search for new classes of objects & transients only visible via LF coherent radiation
- Etc,



Angular resolution (arcmin) vs. frequency (MHz)

SIRA orbit/constellation

- "Retrograde" orbit – stable, no orbit maintenance
- Orbit radius ~5 x10^5 km – closer than L1, etc.
- Orbital period ~40 days
- Fast orbit circularization with lunar flyby
- a Lunar Periodic Orbit, "classified as a Symmetric Doubly Asymptotic Orbit in the Restricted Three-Body Problem"
- 2π views of magnetosphere



- Constellation: 12-16 sats on a spherical shell
- Initial radius ~5 km
- Final radius ~25 km?

SIRA Key Numbers

Frequency range ~ 30 kHz – 15 MHz; sampling at 12-16 frequencies
Antennas – 10 m crossed dipoles
Constellation radius – 5 -> 25 km
Angular resolution (3 MHz) ~ 30 -> 0.5 arcmin (formal)
Field of view – 4 π ster
Theoretical Sensitivity (3 MHz) ~ 10 Jy (1 σ, 5 minutes)
Dynamic range (30 sec snapshot) < 100
Data stream – 2 bit visibilities
Downlink data rate – 8 Mbps (X-band)
Total daily data volume – 40 GB (assuming 2 passes per day)
Ranging requirement ~3 m
Mission lifetime – 2 year prime + 2 year extended mission
MIDEX AO: AO out in summer 2005 at earliest; due 12/2005?
Earliest launch ~ 2011 (MIDEX-7)
MIDEX cost cap: 170 million USD

Collaborating Institutions & Co-I's

- Goddard Space Flight Center
- Jet Propulsion Laboratory
- Naval Research Laboratory
- Mass. Institute of Technology
- UC Berkeley
- Uppsala University
- Catholic University
- University of Iowa
- Nat'l Radio Astronomy Observatory
- Lockheed Martin
- Observatoire de Paris-Meudon
- Swinburne University
- And other university and international partners

Summary

- a mission central to NASA Sun Earth Connections , LWS, & Exploration Initiative goals and objectives
- first high resolution images of solar radio emissions at < 15 MHz (0-1 AU)
- built on GSFC, JPL, NRL's & other Co-I's considerable expertise in solar, heliospheric, planetary, and astrophysical space-based radio astronomy
- an ideal entry position for a significant microsatellite constellation (12-16 microsats) with simple spacecraft and instruments in a moderate radiation environment
- a significant opportunity to conduct interferometry from space with applications to many future missions

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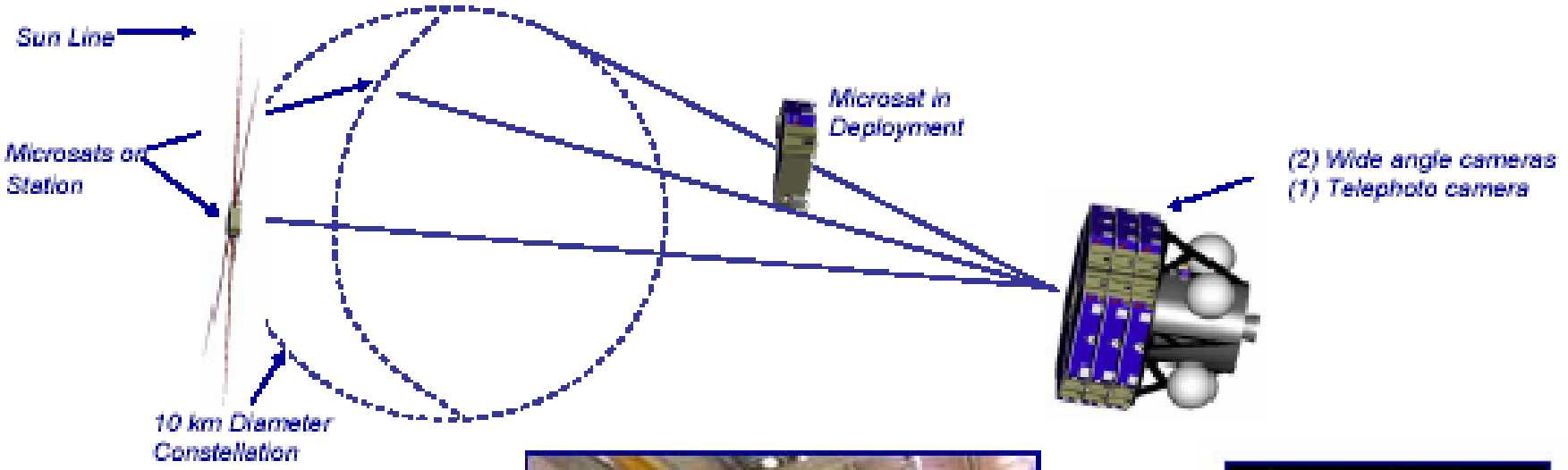
Ranging/timing requirements

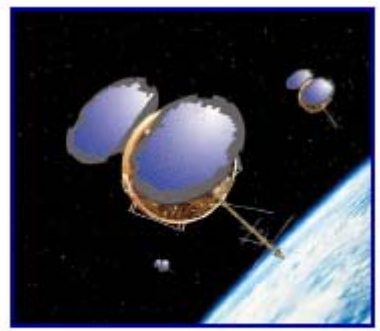
- Ranging requirement ~3 m
- Intent is to range with multitone UHF system
- Relative locations of μsats determined by solving over-detemined solution for all range data

- Absolute timing – 0.1 ± 0.01 sec
- Relative timing (bit stream alignment) – 1 μsec
- Phase stability (fractional frequency stability – 10^{-10})

- Interferometry (aperture synthesis) from space will benefit many future NASA missions

Deployment sequence





ROCSAT-3 - Science & Technology
Launch Aug '05